

(12)

EUROPEAN PATENT APPLICATION

(21) Application number: 84110820.2

(51) Int. Cl.⁴: **H 01 M 8/04**
H 01 M 8/24

(22) Date of filing: 11.09.84

(30) Priority: 14.09.83 JP 168204/83

(43) Date of publication of application:
17.04.85 Bulletin 85/16

(84) Designated Contracting States:
CH DE FR GB LI NL

(71) Applicant: **HITACHI, LTD.**
6, Kanda Surugadai 4-chome Chiyoda-ku
Tokyo 100(JP)

(72) Inventor: **Shimizu, Toshio**
3473-3, Higashiishikawa
Katsuta-shi(JP)

(72) Inventor: **Setou, Takanori**
31-6, Kujicho
5-chome Hitachi-shi(JP)

(72) Inventor: **Tsukul, Tsutomu**
15-6, Ishinazakacho-1-chome
Hitachi-shi(JP)

(72) Inventor: **Dol, Ryouta**
308-2, Nukataminamigo Nakamachi
Naka-gun Ibaraki-ken(JP)

(72) Inventor: **Yamaguchi, Motoo**
7-2-8, Kanesawacho
Hitachi-shi(JP)

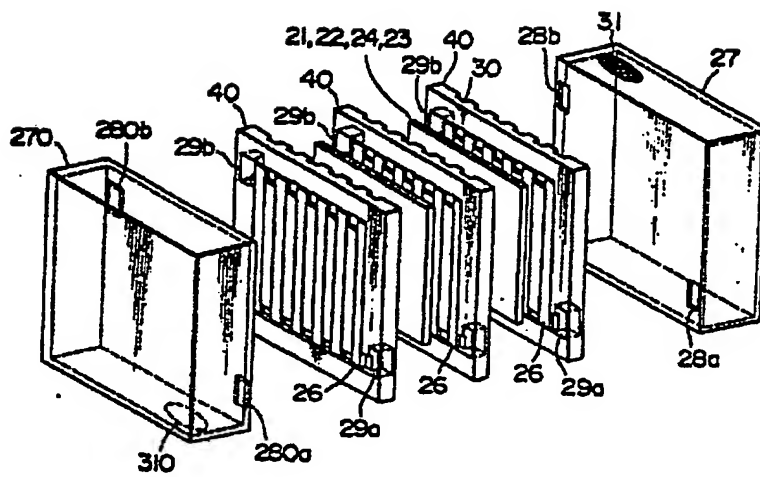
(74) Representative: **Strehl, Schübel-Hopf, Schulz**
Widenmayerstrasse 17 Postfach 22 03 45
D-8000 München 22(DE)

(64) Liquid fuel cell.

(57) In a liquid fuel cell including a plurality of series-connected unit cells each including a fuel electrode (23) and an oxidizer electrode (21) disposed opposite to each other with an electrolyte layer (24) being interposed therebetween, a fuel chamber (25) disposed adjacent to the fuel electrode, and an oxidizer chamber (30) disposed adjacent to the oxidizer electrode, and fuel tanks (27, 270) supplying liquid fuel to the fuel chambers, at least two vertically-spaced passages (28b, 29b, 280b; 28a, 29a, 280a) permitting communication of the fuel tanks with all of the fuel chambers are provided so that one of them serves as a passage for liquid fuel while the other serves as a passage for gas produced at the fuel electrodes, the liquid fuel in an amount smaller than the tank volume is charged in each of the fuel tanks to leave a non-charged space, and gas vent ports (31, 310) provided with gas-liquid separating means (5) are disposed midway of the passages and/or on the tank wall portions corresponding to the non-charged spaces defined in the fuel tanks. The liquid fuel cell can satisfactorily generate power at whatever attitude, and gas produced at the fuel electrodes can be vented to the exterior of the cell without leakage of liquid fuel.

EP 0 137 327 A2

FIG. 4



0137327

LIQUID FUEL CELL

1 This invention relates to a fuel cell using
liquid fuel, and more particularly to a liquid fuel cell
of layer-built structure obtained by laminating a
plurality of unit cells or single cells in series with
5 each other.

 The present invention is suitable for application
to a fuel cell in which liquid fuel such as methanol or
hydrazine is used together with a gaseous oxidizing agent
such as oxygen or air or a liquid oxidizing agent such
10 as hydrogen peroxide.

 A fuel cell is a device from which the energy
produced as a result of an electrochemical reaction be-
tween fuel and an oxidizing agent can be derived directly
as electrical energy, and earnest researches and studies
15 are now being made in an attempt to utilize the fuel cell
as a unit for generating electrical power, a power source
for use in an aircraft or a spacecraft, a power source for
use in an unmanned coast or marine equipment, a power
source for use in a stationary or mobile radio equipment,
20 a power source for use in an automobile, a power source
for driving a household electrical appliance or a power
source for driving an electrical appliance for leisure-
time amusement.

 Fuel cells are broadly typically classified into
25 a molten-carbonate electrolyte type operating at high

1 temperatures of about 500°C - 700°C, a phosphate electro-
lyte type operating at about 200°C, and an alkaline
electrolyte type or an acidic electrolyte type operating
at the atmospheric temperature or temperatures lower
5 than about 100°C.

In the molten-carbonate electrolyte type fuel
cell or phosphate electrolyte type fuel cell operating
at temperatures higher than about 200°C, gaseous fuel
such as hydrogen is most frequently used.

10 On the other hand, in the alkaline electrolyte
type fuel cell or acidic electrolyte type fuel cell
operating at temperatures lower than about 100°C, liquid
fuel such as methanol or hydrazine is most frequently used.
Also, in these fuel cells operating at temperatures lower
15 than about 100°C, an aqueous solution of potassium
hydroxide or lithium hydroxide or a dilute sulfuric acid
is most frequently used as the electrolyte.

In the so-called liquid fuel cell using the
liquid fuel such as methanol or hydrazine, gas is produced
20 at the fuel electrode as a result of the electrochemical
reaction. When methanol is used as the liquid fuel,
carbon dioxide gas is produced, while, when hydrazine
is used as the liquid fuel, nitrogen gas is produced.

It is therefore necessary to dispose of the gas
25 produced at the fuel electrode. In the invention dis-
closed in Japanese Patent Application Laid-open No. 56-
97972 (1981) which describes disposal of such a gas, the
anolyte which is the mixture of fuel and an electrolyte

1 is supplied to the fuel chambers via the exterior of the
fuel cell to be circulated through the above route, so
that the gas produced at the fuel electrodes is guided to
the exterior of the fuel cell together with the anolyte,
5 and the gas only is separated from the anolyte to be
vented to the atmosphere.

In the invention disclosed in Japanese Patent
Application Laid-open No. 58-35875 (1983), a gas-liquid
separating layer permeable to the produced gas only is
10 disposed in each of the fuel chambers, so that the
produced gas can be vented to the exterior of the fuel
cell through this gas-liquid separating layers.

Such a manner of gas disposal is effective when
the liquid fuel cell assumes always a predetermined
15 attitude. However, the above manner of gas disposal does
not provide the fundamental solution of the problem when
the liquid fuel cell is used in a different attitude or
when its attitude is suddenly changed due to turnover
during use.

20 There is a sufficient possibility of turnover
of the liquid fuel cell when the fuel cell is used as a
power source for a vacuum sweeper or a lawn mower.

In the former case, a piping system and a
pump for circulation of the anolyte are required. There-
25 fore, accidental turnover of the liquid fuel cell may
damage the connection between the pump and the piping
system, resulting in leakage of the anolyte from the
damaged connection or impossibility of operation of the

1 pump.

In the latter case too, connection of a separate fuel tank to the fuel supply port is required for actual operation of the liquid fuel cell. Therefore, similarly, 5 accidental turnover of the fuel cell may also damage the connection between the fuel tank and the fuel supply port, resulting in leakage of the fuel or impossibility of fuel supply. Further, in the latter case, provision of the gas-liquid separating layers in each of the fuel chambers 10 poses such a problem that the contact area between the fuel electrodes and the fuel is decreased, and a considerable proportion of the surface area of the fuel electrodes cannot participate in the electrochemical reaction.

It is therefore an object of the present invention 15 tion to provide a liquid fuel cell which can operate with a minimized restriction on its attitude during operation.

Another object of the present invention is to provide a liquid fuel cell in which each of the fuel 20 electrodes can make contact with liquid fuel at its entire surface area on the side of the fuel chamber, so that the entirety of the surface area of the fuel electrodes can participate in the electrochemical reaction.

Still another object of the present invention 25 is to provide a quickly startable, liquid fuel cell which can immediately start power generation in response to the supply of an oxidizing agent to its oxidizer chambers.

The present invention is based on the idea that,

1 when gas vent ports, which are permeable to gas only
but not permeable to liquid, are provided at an upper
position and a lower position respectively of a fuel
chamber or a fuel tank, or more preferably, at diagonally
5 upper and lower positions of the fuel chamber or fuel
tank, one of the gas vent ports is always located upper
relative to the other and can vent the gas produced at the
fuel electrode even if the fuel cell might turn over
resulting in a change of its attitude.

10 In the present invention, there are at least two
passages connecting between the fuel tank and the fuel
chambers. These passages act as fuel passages and act also
as gas vent passages for venting gas produced at the fuel
electrodes.

15 These at least two passages are located at such
positions that, when one of them acts as the fuel passage,
the other acts as the gas vent passage. When the number
of the passages is two, they are preferably located at
an upper position and a lower position respectively, and
20 it is more preferable that they are located at an upper
position and a lower position on a diagonal line.

Each of the at least two passages and/or the
fuel tank are provided with gas venting means. This gas
venting means may be provided in each of the at least
25 two passages only or may be provided on the fuel tank
only. It is needless to mention that the gas venting
means may be provided for both of the at least two passages
and the fuel tank. The gas venting means provided on the

1 fuel tank is preferably located at such a position that
gas produced at the fuel electrodes and discharged into
the fuel tank by way of one of the at least two passages
can be easily vented to the atmosphere.

5 When the gas venting means is provided on the
fuel tank only, at least two should be provided. They
are preferably located at an upper position and a lower
position respectively, and it is more preferable that
they are located at an upper position and a lower position
10 on a diagonal line.

Each of the gas venting means includes a gas
vent port having the function of gas-liquid separation.

Gas accumulating means is provided between the
at least two passages and the gas venting means provided
15 in the passages or between the fuel tank and the gas
venting means provided on the fuel tank. This gas
accumulating means is achieved by arranging so that the
area adjacent to and including the associated gas venting
means is not filled with liquid fuel. For example, when
20 the fuel tank is provided with the gas venting means, the
liquid fuel is not charged to fill the fuel tank but the
amount of liquid fuel charged in the fuel tank is smaller
than the volume of the fuel tank thereby leaving, in the
upper part of the fuel tank, a non-charged space which is
25 not filled with the liquid fuel. Gas accumulates in this
space.

Similarly, when each of the passages connecting
between the fuel chambers and the fuel tank is provided

1 with the gas venting means, the liquid fuel does not fill
the passage acting as the gas vent passage, thereby
leaving, in the upper portion of the passage, a non-
charged space in which gas can accumulate.

5 By arranging in the manner above described, gas
produced at the fuel electrodes can be vented from one
of the gas vent ports to the atmosphere depending on the
changed attitude of the fuel cell, so that the fuel cell
can satisfactorily operate regardless of its attitude.

10 Further, by arranging so that one of the at
least two passages connecting between the fuel tank and
the fuel chambers can supply fuel to the fuel chambers
when the attitude of the fuel cell changes over an angle
of more than 45°, fuel can be reliably supplied to the
15 fuel chambers at whatever attitude of the fuel cell.
Thus, the fuel cell can immediately start power generation
or can make quick start in response to the supply of an
oxidizing agent to its oxidizer chambers.

I. Structure of fuel cell

20 A general structure of a liquid fuel cell is such
that a plurality of unit cells, each comprising the combi-
nation of a fuel chamber, a fuel electrode, an electrolyte
layer, an oxidizer electrode and an oxidizer chamber
arranged in the above order, are connected in series to
25 generate a desired voltage. When the electromotive force
of the unit cell is 0.6 volts, a series connection of 20
unit cells constitutes a fuel cell generating an

1 electromotive force of 12 volts. Therefore, the individual components should be in the form of planar members each having a smallest possible thickness.

5 In an embodiment of the liquid fuel cell according to the present invention, a fuel tank is provided at one end or both ends of the series connection of unit cells. This fuel tank may be fixed to the end cell or may be in a detachable cassette form.

10 The fuel tank has at least two holes for fuel supply, and these holes are disposed in a relation angularly spaced apart by more than 45° , so that liquid fuel can be supplied from one of the holes even when the fuel cell is tilted at an angle of more than 45° .

15 The fuel cell of the present invention can be used in a state carried on the operator's shoulder, and it is expected that such a mode is most frequent.

20 In such a case, the fuel cell is tilted at an angle of about 45° or more. It is therefore required that the fuel cell can satisfactorily operate even when it is tilted at an angle of more than 45° . The aforementioned holes are preferably disposed at an upper position and a lower position on a diagonal line. These holes serve also as gas vent passages conducting gas produced at the fuel electrodes toward and into the fuel
25 tank. It is therefore desirable that the level of fuel contained in the fuel tank is kept lower than the position of the upper one of the holes so that the upper hole may not be submerged in the fuel.

1 It is necessary that the fuel chamber situated
near the holes provided on the fuel tank is also provided
with holes serving as both fuel supply ports and gas
vent passages, so that fuel can be supplied to or gas
5 can be discharged from the fuel chamber through the holes
provided on the fuel tank and fuel chamber. The fuel
chamber is generally provided by forming a recess in a
separator of carbon. It is therefore desirable to bore
such holes in the separator.

10 By the arrangement above described, liquid
fuel is supplied to the fuel chambers through the lower
one of the holes of the fuel tank, and the fuel chambers
are filled with the fuel up to the same level as the fuel
level in the fuel tank.

15 Gas vent ports for venting gas produced at the
fuel electrodes to the exterior of the fuel cell can be
provided on the fuel chambers or the fuel tank, or midway
of the passages connecting between the fuel chambers and
the fuel tank, or at a plurality of positions as desired.
20 However, since the individual members constituting the
unit cells of the fuel cell of layer-built structure should
be as thin as possible as described already, the gas vent
ports are desirably provided on the fuel tank or midway
of the passages connecting between the fuel chambers and
25 the fuel tank.

 The gas vent ports are required to be permeable
to gas only but impermeable to liquid. As this means, a
selectively permeable membrane such as a membrane of a

1 fluoro carbon resin, a membrane of a silicone resin, a
cloth subjected to liquid proofing treatment or a nonwoven
cloth of plastic fibers having a liquid repelling
property, as disclosed in Japanese Patent Application
5 Laid-open No. 56-97972 (1981), can be used. Also, the
materials used to form the gas-liquid separating layer in
Japanese Patent Application Laid-open No. 58-35875 (1983)
can be used. However, gas-liquid separating means employed
in the present invention should be more carefully selected
10 since the liquid pressure of fuel is also imparted to
the gas vent ports. Functions desired for the gas-liquid
separating means are that the gas-liquid separating
means is free from liquid leakage regardless of impartation
of the liquid pressure for a long period of time when it
15 is submerged in the fuel or placed in the fuel-charged
part and that the gas-liquid separating means can easily
discharge the produced gas without increasing the loss of
the gas pressure when it is not submerged in the fuel or
placed in the non-charged part. For this purpose, it is
20 preferable to employ a sheet formed by pressing under heat
a mass of intertwined fibers of a liquid repellent
material. A woven fabric formed of intertwined fiber
filaments or a nappy nonwoven cloth is not suitable for
use as the gas-liquid separating means. The former
25 material is greatly advantageous over the latter material
in that the resistance to permeating gas is low at the
same average diameter of the pores.

The gas-liquid separating means having the

1 functions described above are provided on the fuel tank
or the fuel chambers or disposed midway of the combined
fuel passages and gas vent passages connecting between
the fuel tank and the fuel chambers for venting the
5 produced gas therethrough, so that the restrictions on
the attitude of the fuel cell during operation can be
minimized.

When one fuel tank is disposed on each side of
the fuel cell, that is, when a total of two fuel tanks are
10 provided, only one gas vent port may be provided on each
fuel tank. In such a case, preferably, the gas vent
port is located at an upper position of one of the opposing
fuel tanks, and the other gas vent port is located at a
lower position of the other fuel tank. It is more prefer-
15 able that these two gas vent ports are located at diagonal
upper and lower positions on the two fuel tanks respec-
tively.

When thus two fuel tanks are provided, it is
desirable that fuel tanks having different volumes are
20 combined. In such a case, it is desirable that the volume
of the larger fuel tank is more than two times as large
as that of the smaller fuel tank. This is because, when
the two fuel tanks have the same volume, the greater
part of fuel in the upper fuel tank will return into the
25 lower fuel tank when the fuel cell operates in a state in
which the fuel cell stands vertical or orthogonal with
respect to the laminated direction of the unit cells,
resulting in impossibility of operation of the fuel cell

1 or generation of a lower output than that normally
provided by the layered unit cells and resulting also in
a shortened useful service life of the fuel cell.

Employment of the fuel tanks having different volumes is
5 advantageous in that, when the fuel tank having the
smaller volume is situated lower than the fuel tank
having the larger volume, fuel can be reliably supplied
to the upper part of the fuel chambers, so that a high
output can be delivered.

10 Provision of the two fuel tanks exhibits also
such an additional effect that gas produced at the fuel
electrodes can be more easily discharged from the fuel
chambers than when only one fuel tank is provided. Provi-
sion of the two fuel tanks exhibits such another effect
15 that dropping of the level of fuel in the fuel chambers
with the operation of the fuel cell can be retarded. In
order that such effects can be sufficiently exhibited,
it is desirable that the volume of the fuel tank having
the smaller volume is not smaller than 1/5 of the volume
20 of the fuel tank having the larger volume.

It is desirable to employ an organic high-
molecular electrolyte impermeable to the liquid fuel so
that the fuel in the fuel chambers may not migrate toward
areas except the fuel electrodes and so that the fuel
25 can be continuously supplied to the fuel chambers even
when the fuel cell is not in operation. Employment of
such an electrolyte is advantageous in that generation of
power is immediately started or quick starting can be

1 attained as soon as an oxidizing agent is supplied to
the oxidizer chambers.

In the present invention, methanol can be used
as the fuel. In this case, methanol may migrate toward
5 and into the electrolyte chambers by permeating through
the fuel electrodes and may finally reach the oxidizer
electrodes to be oxidized or ignited thereat.

To prevent such an undesirable situation, a
separator partition for suppressing permeation of the
10 methanol is preferably interposed between the fuel
electrodes and the electrolyte chambers. An example of
this separator partition is an ion exchange membrane.

II. Electrolyte

In the liquid fuel cell of the present invention,
15 an acidic or basic electrolyte can be used. A liquid or
solid electrolyte can also be used.

However, when a liquid electrolyte is used, the
electrolyte which should remain in the electrolyte chambers
may pass through the porous fuel electrodes to flow into
20 the fuel chambers due to the dilution phenomenon attributable
to the concentration gradient between the electrolyte and
the liquid fuel.

To avoid the above phenomenon, a fuel mixture
in which the fuel is diluted with the electrolyte (which
25 mixture is generally called an anolyte) is preferably
supplied to the fuel chambers. By the supply of the
anolyte, the concentration difference between the liquid

1 fuel and the electrolyte can be decreased to minimize
flow-out of the electrolyte from the electrolyte chambers
toward and into the fuel chambers. However, dilution of
the fuel with the electrolyte is an unnecessary counter-
5 measure from the aspect of the primary functions of the
fuel cell in that the concentration of the liquid fuel
is correspondingly lowered, and power is consumed for
circulation of the electrolyte rather than circulation of
the fuel, resulting in a reduced efficiency of energy
10 utilization. Further, the supply or circulation of the
highly corrosive electrolyte together with the fuel is
objectionable to the user in addition to the severe
restrictions on the materials constituting the fuel cell.

Employment of a solid electrolyte can solve
15 all of the aforementioned problems encountered with the
liquid electrolyte.

It is desirable to employ an organic high-
molecular electrolyte such as polystyrene sulfonate as
the solid electrolyte.

20 As an example of the method for forming the
organic high-molecular electrolyte layer, an ion exchange
membrane is fixed in an electrolyte supporting frame
member, and the aforementioned electrolyte composition is
supported on one surface or both surfaces of the membrane.
25 According to such a method, the thickness of the electrolyte
layer structure can be made very small, and the assembling
of the fuel cell can also be facilitated.

The electrolyte supporting frame member is

- 1 preferably made of an electrical insulating material and
may, for example, be a plate, a sheet or a film of a
suitable one of various plastic materials. When a thickener
or a spacer is blended in the electrolyte composition,
5 short-circuit between the electrodes can be prevented.

According to another method, the organic high-molecular electrolyte composition described above is supported in a dry state or in a paste form on a frame member having a thickness of 0.1 mm to 5 mm, especially,
10 0.3 mm to 2 mm, to provide a thin electrolyte layer structure. It is also effective to coat the organic high-molecular electrolyte composition on the opposing surface of the oxidizer electrodes and/or the fuel electrodes.

- The solid electrolyte is advantageous over the
15 liquid electrolyte in that the high assembling precision required for a fuel cell using the liquid electrolyte is unnecessary, and there are less restrictions on the materials of the gas-liquid separating means. The solid electrolyte is further advantageous over the liquid
20 electrolyte in that, even when the cell frame is ruptured due to fuel-cell handling failure, for example, accidental drop or impingement with an obstacle, the solid electrolyte would not leak to the exterior of the fuel cell, whereas the liquid electrolyte leaks easily to the exterior of
25 the fuel cell.

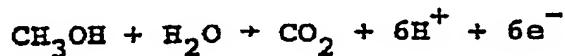
The term "solid electrolyte" is used in the present invention to exclude that not containing any liquid components but include also that in which a high-molecular

- 1 electrolyte is dissolved in water and a thickener is added as required to provide a pasty electrolyte.

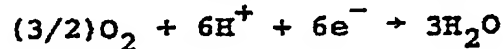
III. Fuel chamber

- The electrochemical reaction in a fuel cell, for
5 example, a methanol fuel cell is as follows:

Fuel electrode (negative electrode)



Oxidizer electrode (positive electrode)



- In order that the electrochemical reaction described above can effectively proceed at the fuel electrode, it is desirable that the fuel makes continuous contact with the fuel electrode up to the uppermost end
10 of the latter so that the entire surface of the fuel electrode can be utilized for the reaction.

- However, a portion which is not in contact with the fuel is left at the upper part of the fuel electrode, since the liquid level in the fuel chamber is the same
15 as that in the fuel tank, and the fuel is not contained in the fuel tank to completely fill the fuel tank. Also, due to progressive consumption of the fuel with the operation of the fuel cell, the contact area between the fuel electrode and the fuel decreases progressively.

- 20 In order that the fuel electrode can be charged with the fuel under such a situation, it is effective to provide, in the fuel chamber, a fibrous sucking member.

1 capable of sucking the fuel by the capillary action.

As a base material of this sucking member, an organic or inorganic fibrous material such as paper, cotton or asbestos glass, or an synthetic fibrous material
5 such as acrylic fibers, aromatic polyamide fibers, nylon fibers, polyamide-imide fibers, polyester fibers or polypropylene fibers can be used. An acid or alkali resistive material is especially preferable from the aspect of the property of material. When a natural,
10 organic fibrous base material is employed, it is effective to treat or impregnate it with resin varnish. It is needless to mention that the amount of the resin varnish is suitably limited so that the capillary action may not be lost. Besides the fibrous base materials above described,
15 a porous sheet such as a sheet obtained by sintering powder of an inorganic material such as alumina or silica may be employed. In this case, a hydrophilic material is more preferable. However, the inventors have experimentally confirmed that a hydrophobic material can also be used
20 when the fuel is, for example, methanol which shows an affinity to carbon. Although the thickness of the capillary member is not primarily determined but is variable depending on the material and porosity, a value of more than 10 μm is suitable from the viewpoints of
25 strength and anti-swellability.

This method of fuel supply by means of such a sucking member is especially effective when a solid electrolyte is employed. This is because, in a fuel cell

1 using a liquid electrolyte, supply of anolyte to the fuel
chambers is required, and the amount of dilute sulfuric
acid in the fuel chambers occupies 50 to 70% by volume
in the case of an ordinary fuel cell. Because of such
5 a low concentration of methanol, supply of a sufficient
amount of fuel up to the uppermost end of the fuel
electrodes is difficult according to the sucking mode of
fuel supply.

In contrast, in the case where the solid
10 electrolyte is employed, methanol can be supplied to the
fuel chambers singly or with water added in a small amount
required for the reaction. Therefore, the fuel can be
sufficiently supplied up to the uppermost end of the fuel
electrodes according to the sucking mode of fuel supply.

15 It is apparent from the above discussion that
employment of a solid electrolyte and fuel supply accord-
ing to the sucking mode are most desirable in the fuel
cell of the present invention.

The present invention will be apparent from the
20 following detailed description taken in conjunction with
the accompanying drawings, in which:

FIG. 1 is an exploded perspective view showing
a unit cell in an embodiment of the fuel cell according
to the present invention;

25 FIG. 2 is a perspective view schematically
showing the level of fuel contained in the fuel tank shown
in FIG. 1;

FIG. 3 is a perspective view showing another

1 form of the fuel tank;

FIG. 4 is an exploded perspective view of another embodiment of the fuel cell of the present invention comprising a plurality of stacked or laminated unit cells;

5 FIG. 5 is a perspective view of still another embodiment of the layer-built type fuel cell according to the present invention;

FIG. 6 is a sectional view showing one form of the structure of the gas vent port employed in the
10 present invention;

FIG. 7 is an exploded perspective view of yet another embodiment of the present invention to illustrate how fuel is supplied and gas is vented; and

FIG. 8 is a perspective view showing the structure of the fuel chamber employed in the present invention.
15

Preferred embodiments of the present invention will now be described in detail with reference to the drawings.

FIG. 1 is an exploded perspective view showing
20 the structure of a unit cell in an embodiment of the methanol-air fuel cell according to the present invention.

Referring to FIG. 1, the unit cell is composed by successively superposing a separator 20 of graphite serving as both an air chamber and a current collector,
25 an air electrode 21 disposed adjacent to the separator 20, an ion exchange membrane 22, an organic high-molecular electrolyte layer 24 disposed adjacent to a methanol electrode 23, and another separator 25 of graphite serving

1 as both a fuel chamber and a current collector. Grooves
30 are formed on one surface of the separator 20 to
provide air passages. The methanol electrode 23 and air
electrode 21 are provided by blending particles of a
5 catalytic, active noble metal such as platinum with
conductive particles such as particles of carbon black or
acetylene black, and coating the blend on a conductive
base member such as a carbon paper or a wire gauze of a
metal showing a corrosion resistance against acids or
10 alkalis. The blend containing the catalytic active
component is provided at least on the electrolyte-side
surface of the methanol electrode 23 and air electrode 21.

In the embodiment shown in FIG. 1, the separator
25 is provided with a plurality of sucking strips 26 for
15 sucking methanol supplied from a methanol tank 27 to the
fuel chamber 25. The methanol tank 27 is disposed in
contact with the other surface of the separator 25 remote
from the surface facing the methanol electrode 23. Holes
28a and 28b are provided at diagonally lower and upper
20 positions respectively on the wall of the methanol tank
27 making contact with the separator 25. Holes 29a and
29b are also provided in the separator 25 at positions
corresponding to those of the holes 28a and 28b respec-
tively. These holes serve as passages for supplying
25 methanol and also as passages for discharging gas produced
at the methanol electrode 23. The level of methanol
contained in the methanol tank 27 is lower than the position
of the hole 28b in the state shown in FIG. 1. In the

1 state shown in FIG. 1, methanol contained in the methanol
tank 27 flows out from the hole 28a to enter the fuel
chamber 25 through the hole 29a and is sucked by the sucking
strips 26 to be charged up to the upper part of the fuel
5 chamber. Gas produced at the methanol electrode 23 as a
result of the electrochemical reaction flows out from
the hole 29b to enter the methanol tank 27 through the
hole 28b and is vented to the exterior of the fuel cell
through a gas vent port 31 having gas-liquid separating
10 means. In addition to the illustrated gas vent port 31
provided on the top wall of the methanol tank 27, another
gas vent port (not shown) is also provided on the bottom
wall of the methanol tank 27 at a position diagonal with
respect to the former.

15 The structure of the fuel cell does not change
from that shown in FIG. 1 even when the attitude of the
fuel cell is changed over an angle of 180° from that shown
in FIG. 1. Now, methanol flows out from the hole 28b to
enter the fuel chamber through the hole 29b, and gas
20 produced at the methanol electrode 23 flows out from the
hole 29a to enter the methanol tank 27 through the hole
28a and is vented to the exterior of the cell through
the gas vent port (not shown) provided on the bottom wall
of the methanol tank 27 in FIG. 1.

25 Even when the attitude of the fuel cell is
changed over an angle of 90° from that shown in FIG. 1,
the holes serving as the gas vent passage are present at
the upper part of the methanol tank 27 and fuel chamber,

1 and the holes serving as the fuel supply passage are
present at the lower part of the methanol tank 27 and fuel
chamber. Therefore, the fuel cell can satisfactorily
operate at whatever attitude while reliably venting
5 produced gas to the exterior of the cell.

The embodiment shown in FIG. 1 is advantageous
over the prior art methanol fuel cell in that an auxiliary
unit such as a pump for supplying and circulating anolyte
is unnecessary. Thus, the power required for driving
10 this pump can be saved.

FIG. 2 shows schematically the state of methanol
1 contained in the methanol tank 27 shown in FIG. 1. It
is required that the level of the methanol 1 be lower
than the level of the hole 28b. The internal zone of the
15 methanol tank 27 where the methanol 1 is not charged is
utilized as an accumulator for the produced gas which is
to be vented to the exterior of the cell from the gas
vent port 31.

FIG. 3 shows a modification of the methanol
20 tank 27 shown in FIG. 1. In this modification, the holes
28a and 28b are provided in vertically aligned relation
adjacent to one of the marginal edges of the separator-side
wall of the methanol tank 27. These holes 28a and 28b
may be extended toward each other to provide an elongate
25 vertical hole.

In the fuel cell provided with the modified
methanol tank 27 shown in FIG. 3, methanol is supplied to
the fuel chamber from the methanol tank 27 on the side

1 which is the same as the side from which gas produced at
the methanol electrode 23 is discharged into the methanol
tank 27.

Thus, although the fuel cell can satisfactorily
5 operate at the attitude of the methanol tank 27 shown in
FIG. 3 or at a 180°-turned attitude, the fuel cell is
not suitable for operation at a 90°-turned attitude of
the methanol tank 27. Therefore, the satisfactorily
operable attitude of the fuel cell provided with the
10 modified methanol tank 27 shown in FIG. 3 is restricted
when compared with that provided with the methanol tank
27 shown in FIG. 1.

However, the fuel cell provided with the modified
methanol tank 27 is advantageous in that the overall size
15 of the fuel cell can be made small because both the
methanol supply system and the gas vent system are
disposed adjacent to one of the marginal edges of the
separator-side wall of the methanol tank.

In the modified methanol tank 27 shown in
20 FIG. 3, the gas vent ports 31 need not necessarily be
provided at diagonal positions and may be provided at
opposing or vertically aligned positions on the top and
bottom walls respectively of the methanol tank 27 as
illustrated. In another form, the gas vent ports 31 may
25 be provided in vertically spaced relation on one of the
side walls of the methanol tank 27 except the wall making
contact with the fuel chamber.

FIG. 4 shows another embodiment of the fuel cell

1 of the present invention in which a plurality of unit cells
are connected in series with each other, and methanol tanks
are provided on the both ends respectively of the laminate.
In FIG. 4 in which the same reference numerals are used
5 to designate the same or equivalent parts appearing in
FIG. 1, the methanol electrode, electrolyte layer, ion
exchange membrane and air electrode are shown by a single
plate to avoid confusion of illustration. The fuel chamber
and air chamber are formed on the respective surfaces of
10 each of common separators 40 of graphite. That is, grooves
30 are formed on one of the surfaces of each of the
separators 40 of graphite to provide air passages, and
a recess is formed on the other surface to receive the
fuel sucking strips 26 therein.

15 By the lamination of the plural unit cells,
the holes 29a and 29b provided on the individual separators
40 communicate with each other to provide the passage for
supplying methanol from the methanol tanks 27 and 270 to
the fuel chambers and also to provide the passage for
20 discharging gas produced at the methanol electrodes 23.

When the parts of the individual unit cells are
formed to include these passages or when a frame member
of, for example, a plastic material including those
passages is separately molded and the components of the
25 individual unit cells are inserted in the molded frame
member, a fuel cell which is structurally compact can be
assembled.

It is preferable that, after lamination of the

- 1 plural unit cells, end plates are put on both sides of
the laminate and fastened by fastening members such as
bolts so that the contact resistance between the laminated
unit cells may not become high. Alternatively, the
5 components of the individual unit cells may be bonded and
fixed together by an adhesive.

Referring to FIG. 4, the methanol tanks 27 and
270 are provided on both sides of the laminated unit cells
to sandwich the laminate therebetween, and gas vent
10 ports 31 and 310 are provided on the top wall of the fuel
tank 27 and on the bottom wall of the other fuel tank
270 respectively. These gas vent ports 31 and 310 are
disposed at diagonal positions as shown. One or both
of these gas vent ports 31 and 310 may be arranged to be
15 removable so as to replenish fuel therefrom.

Provision of such two methanol tanks 27 and 270
as shown in FIG. 4 is advantageous in that a single fuel
tank of large capacity need not be provided when operation
of the fuel cell for a long period of time is required,
20 and a fuel tank of large capacity must be used. Further,
one or both of these two fuel tanks are preferably of
the cartridge type so that, with the consumption of fuel
contained in the tank, the tank can be replaced by a new
one to re-raise the level of fuel. In such a case, how-
25 ever, means must be provided so that, when the fuel tank
is detached from the fuel cell, methanol present in the
fuel cell or the methanol remaining in the fuel tank may
not leak out from the connection therebetween. As this

1 preventive means, gas-liquid separating means similar to that provided in the gas vent port are preferably provided on the fuel cell and fuel tank or tanks adjacent to the connection or connections.

5 In the fuel cell shown in FIG. 4, methanol is supplied from the fuel tanks 27 and 270 to the fuel chambers through the respective holes 28a and 280a. On the other hand, gas produced at the methanol electrodes 23 flows through the holes 29b and 28b to accumulate in
10 the internal space of the methanol tank 27 not charged with the fuel and is then vented to the exterior of the fuel cell from the gas vent port 31.

The fuel cell having the structure shown in FIG. 4 can satisfactorily operate and gas produced at the
15 methanol electrodes can be vented to the exterior of the fuel cell even when its attitude change brings the methanol tank 27 to an upper position relative to the methanol tank 270 and vice versa.

Further, the fuel is supplied to the fuel
20 chambers only through the holes bored in the separators 40, and the fuel is charged into the fuel chambers even in the non-operating period of the fuel cell. Therefore, supply of an oxidizing agent to the oxidizer chambers can immediately initiate generation of the power thereby
25 ensuring quick starting of the fuel cell operation.

FIG. 5 shows still another embodiment of the fuel cell of the present invention in which a plurality of unit cells are laminated in series with each other,

1 and methanol tanks are provided on the both ends respec-
tively of the laminate. In this embodiment, gas vent
ports 98 and 99 are not provided on the methanol tanks
27 and 270 but are provided on the separators of graphite
5 (not shown), so that produced gas can be vented to the
exterior of the fuel cell at positions midway of the
passages supplying methanol to the fuel chambers from the
methanol tanks. Such gas vent ports are also provided at
lower positions on the other side of the fuel cell.

10 Thus, gas produced at the fuel electrodes can
be effectively vented to the exterior of the fuel cells
even when the gas vent ports are provided midway of the
fuel supply passages. In FIG. 5, reference numerals 111
and 112 designate terminals.

15 FIG. 6 shows one form of the structure of the
gas vent port in the present invention. Although FIG. 6
illustrates the case where the gas vent port is disposed
on the top wall of the methanol tank 27, it is apparent
that the structure is the same when the gas vent port is
20 disposed on the bottom wall of the methanol tank 27, and
it is also apparent that the same applies to the case
where the gas vent port is disposed on the separator.

The requirements for the gas vent port are
that no leakage of fuel occurs even when the attitude of
25 the fuel cell makes a turn of 180° or 90° from that shown
in FIG. 1 or FIG. 4 and that gas produced at the fuel
electrode can be vented to the exterior of the fuel cell
even after impartation of the liquid pressure.

1 To satisfy the above requirements, it is necessary to provide gas-liquid separating means in the gas vent port. Preferred gas-liquid separating means is provided by a porous sheet or a very thin film of thickness
5 less than 50 μ m obtained by pressing under heat an entwined mass of fibers of a liquid repellent material such as a fluoro carbon resin, polystyrene or polyethylene.

 However, when such a sheet or film is singly used, it is easily damaged by the liquid pressure due
10 to its low mechanical strength. A structure as shown in FIG. 6 is therefore desirable.

 Referring to FIG. 6, a porous film 5 of a liquid repellent material as described above is reinforced by a cap 6 made of a material which is strong enough to
15 withstand the liquid pressure. The cap 6 is formed with a plurality of perforations 6a, 6b and 6c permitting flow of gas therethrough. The material of the cap 6 is, for example, the same as that of the methanol tank 27. In the form shown in FIG. 6, the cap 6 is screwed onto a
20 mating tap of the tank 27 so that it serves also as a fuel inlet to the tank 27.

 A porous reinforcement 7 is preferably interposed between the cap 6 and the liquid-repellent porous film 5 so as to minimize the possibility of rupture of
25 the liquid-repellent porous film 5.

 FIG. 7 shows yet another embodiment of the fuel cell of the present invention in which a combined fuel passage and gas vent passage extends through the

1 central area of the methanol electrode or air electrode.

Such an arrangement is advantageous in that the path for supplied fuel and vented gas in the fuel chamber can be shortened.

5 FIG. 8 shows one form of the structure of the fuel chamber employed in the present invention. The fuel chamber may be such that a fuel receiving recess is merely formed on a liquid impermeable plate of carbon. It is desirable, however, that a liquid receiving recess
10 is formed on a liquid impermeable plate of carbon, and sucking strips 26 are disposed in this recess as shown in FIG. 8. By the provision of such sucking strips 26, fuel can make contact with the entire surface of the fuel electrode.

15 While preferred embodiments of the present invention have been described in detail with reference to the drawings, the present invention is in no way limited to such specific embodiments, and various changes and modifications may be made therein without departing from
20 the scope of appended claims.

For example, the present invention is also applicable to liquid fuel cells other than the methanol fuel cell, and methanol tanks may be disposed on lateral sides of the fuel chambers in the fuel cell structure
25 shown in FIG. 4.

It will be understood from the foregoing detailed description that the liquid fuel cell according to the present invention can reliably generate power at whatever

- 1 attitude, and produced gas only can be vented to the exterior of the fuel cell without causing leakage of fuel. Further, supply of an oxidizing agent to the oxidizer chambers can cause quick starting of the fuel
- 5 cell.

CLAIMS

1. A liquid fuel cell including a fuel electrode (23) and an oxidizer electrode (21) disposed opposite to each other with an electrolyte layer (24) being interposed therebetween, a fuel chamber (25) disposed adjacent to said fuel electrode, an oxidizer chamber (30) disposed adjacent to said oxidizer electrode, and a fuel tank (27) supplying liquid fuel to said fuel chamber, said fuel cell comprising means (28a, 29a; 28b, 29b) for conducting gas produced at said fuel electrode toward the exterior of the fuel cell, gas venting means including gas vent ports (31) for venting said gas conducted toward the exterior of the fuel cell to the atmosphere, means formed between said gas conducting means and said gas venting means for accumulating said gas therein, said gas venting means including at least two gas vent ports (31) so that said gas can be vented to the atmosphere from one of said gas vent ports when the attitude of the fuel cell tilts over an angle of more than 45° from the normal attitude, and gas-liquid separating means (5) disposed in each of said gas vent ports.
2. A liquid fuel cell as claimed in Claim 1, wherein said gas-liquid separating means (5) is in the form of a porous member of a liquid repellent material.
3. A liquid fuel cell as claimed in Claim 1, wherein said means (28a, 29a; 28b, 29b) for conducting said gas toward the exterior of the fuel cell is connected to said fuel tank (27), and said gas venting means and

said gas accumulating means are disposed midway of the path leading to said fuel tank.

4. A liquid fuel cell including a fuel electrode (23) and an oxidizer electrode (21) disposed opposite to each other with an electrolyte layer (24) being interposed therebetween, a fuel chamber (25) disposed adjacent to said fuel electrode, an oxidizing chamber (30) disposed adjacent to said oxidizer electrode, and a fuel tank (27) supplying liquid fuel to said fuel chamber, said fuel cell comprising means (28a, 29a; 28b, 29b) for conducting gas produced at said fuel electrode toward and into said fuel tank (27), a non-charged space defined in said fuel tank (27) for accumulating said gas therein, gas venting means including gas vent ports (31) for venting said gas accumulating in said non-charged space to the exterior of said fuel tank, said gas venting means including at least two gas vent ports (31) so that said gas can be vented to the exterior of said fuel tank from one of said gas vent ports when the attitude of the fuel cell tilts over an angle of more than 45° from the normal attitude, and gas-liquid separating means (5) disposed in each of said gas vent ports.

5. A liquid fuel cell as claimed in Claim 4, wherein said gas vent ports (31) are disposed at an upper position and a lower position respectively on said fuel tank (27).

6. A liquid fuel cell as claimed in Claim 4, wherein said gas vent ports (31) are located at diagonally upper and lower positions respectively.

7. A liquid fuel cell including a fuel electrode (23) and an oxidizer electrode (21) disposed opposite to each other with an electrolyte layer (24) being interposed therebetween, a fuel chamber (25) disposed adjacent to said fuel electrode, an oxidizer chamber (30) disposed adjacent to said oxidizer electrode, and a fuel tank (27) supplying liquid fuel to said fuel chamber, said fuel cell comprising a first passage (28b, 29b) connecting between a non-charged space in said fuel tank (27) and said fuel chamber (25), a second passage (28a, 29a) disposed at a position diagonal with respect to said first passage for supplying said fuel from said fuel tank to said fuel chamber, and gas venting ports (31) provided with gas-liquid separating means (5) and disposed on at least one of said non-charged space of said fuel tank (27) and said first passage (28b, 29b) communicating therewith and also disposed on at least one of the fuel-charged space of said fuel tank and said second passage (28a, 29a) communicating therewith.

8. A liquid fuel cell as claimed in Claim 7, wherein said gas vent ports (31) are disposed at diagonally upper and lower positions respectively on said fuel tank (27).

9. A liquid fuel cell including a fuel electrode (23) and an oxidizer electrode (21) disposed opposite to each other with an electrolyte layer (24) being interposed therebetween, a fuel chamber (25) disposed adjacent to said fuel electrode, an oxidizer chamber (30) disposed

adjacent to said oxidizer electrode, and a fuel tank (27) supplying liquid fuel to said fuel chamber, said fuel cell comprising means (28a, 29a; 28b, 29b) for conducting gas produced at said fuel electrode toward the exterior of the fuel cell, gas venting means including gas vent ports (31) for venting said gas conducted toward the exterior of the fuel cell to the atmosphere, means formed between said gas conducting means and said gas venting means for accumulating said gas, said gas venting means including at least two gas vent ports (31) so that said gas can be vented to the atmosphere from one of said gas vent ports when the attitude of the fuel cell tilts over an angle of more than 45° from the normal attitude, gas-liquid separating means (5) disposed in each of said gas vent ports, and fuel sucking means (26) for sucking the fuel into said fuel chamber.

10. A liquid fuel cell as claimed in Claim 9, wherein said fuel sucking means is formed of a material exhibiting the capillary action.

11. A liquid fuel cell as claimed in Claim 9, wherein said electrolyte is a solid electrolyte.

12. A liquid fuel cell including a plurality of series-connected unit cells each including a fuel electrode (23) and an oxidizer electrode (21) disposed opposite to each other with an electrolyte layer (24) being interposed therebetween, a fuel chamber (25) disposed adjacent to said fuel electrode, and an oxidizer chamber (30) disposed adjacent to said oxidizer electrode, and a fuel tank

(27, 270) supplying liquid fuel to said fuel chambers, said fuel cell comprising a passage (28b, 29b) connecting between a non-charged space in said fuel tank (27, 270) and said fuel chambers (25) of said unit cells, and gas venting means including a gas vent port (31) provided with gas-liquid separating means (5) and disposed on at least one of said passage and said non-charged space of said fuel tank, said gas venting means including at least two gas vent ports (31) so that gas can be vented from one of said gas vent ports when the attitude of the fuel cell tilts over an angle of more than 45° from the normal attitude.

13. A liquid fuel cell as claimed in Claim 12, wherein a second passage (28a, 29a) is disposed at a diagonally lower position than the position of said first passage (28b, 29b) for supplying liquid fuel contained in said fuel tank (27, 270) to all of said fuel chambers (25) of said unit cells.

14. A liquid fuel cell as claimed in Claim 13, wherein a gas vent port (31) provided with gas-liquid separating means (5) is disposed in said second passage (28a, 29a).

15. A liquid fuel cell as claimed in Claim 13, wherein a gas vent port (31) provided with gas-liquid separating means (5) is disposed in the fuel-charged space of said fuel tank.

16. A liquid fuel cell as claimed in Claim 15, wherein said gas vent port (31) is disposed at a position

diagonal with respect to another gas vent port (31) disposed on at least one of said non-charged space on said fuel tank and said first passage (28b, 29b) communicating with said non-charged space.

17. A liquid fuel cell as claimed in Claim 12, wherein fuel sucking means is provided in said fuel chamber of each of said unit cells.

18. A liquid fuel cell as claimed in Claim 17, wherein said electrolyte is a solid electrolyte.

19. A liquid fuel cell as claimed in Claim 12, wherein said fuel chamber of each of said unit cells is provided by forming a recess on a separator (40) of carbon.

20. A liquid fuel cell as claimed in Claim 19, wherein said separator (40) of carbon is provided with a passage (29b) connecting between the non-charged space of said fuel tank and said fuel chamber.

21. A liquid fuel cell as claimed in Claim 19, wherein said separator (40) of carbon is provided with another passage (29a) for supplying liquid fuel contained in said fuel tank to said fuel chamber.

22. A liquid fuel cell as claimed in Claim 15, wherein said gas vent port (31) is disposed at a position associated with said non-charged space when said fuel tank is turned 180°.

23. A liquid fuel cell as claimed in Claim 18, wherein said liquid fuel is methanol.

24. A liquid fuel cell including a plurality of series-connected unit cells each including a fuel electrode

(23) and an oxidizer electrode (21) disposed opposite to each other with an electrolyte layer (24) being interposed therebetween, a fuel chamber (25) disposed adjacent to said fuel electrode, and an oxidizer chamber (30) disposed adjacent to said oxidizer electrode, and fuel tanks (27, 270) supplying liquid fuel to said fuel chambers, wherein said fuel tanks are disposed on both ends respectively of the laminate of said series-connected unit cells, and wherein said fuel cell comprises a passage (28b, 29b, 280b) connecting between at least one of non-charged spaces of said fuel tanks and said fuel chambers, and gas venting means including gas vent ports (31, 310) provided with gas-liquid separating means (5) and disposed on at least one of said passage and said non-charged space of said fuel tank communicating with said passage, said gas venting means including at least two gas vent ports disposed at different positions respectively so that gas can be vented from one of said gas vent ports when the attitude of the fuel cell tilts over an angle of more than 45° from the normal attitude.

25. A liquid fuel cell as claimed in Claim 24, wherein a second passage (28a, 29a, 280a) connecting between at least one of the fuel-charged spaces in said two fuel tanks (27, 270) and said fuel chambers is disposed at a diagonal position with respect to said first passage (28b, 29b, 280b) connecting between said non-charged space and said fuel chambers.

26. A liquid fuel cell as claimed in Claim 25,

wherein a gas vent port (310) provided with gas-liquid separating means (5) is disposed on at least one of said second passage and said non-charged space of said fuel tank communicating with said second passage.

27. A liquid fuel cell as claimed in Claim 25, wherein said gas venting means are provided in the upper non-charged space of one of said fuel tanks (27) and in the lower fuel-charged space of the other fuel tank (310) respectively at positions diagonal with respect to each other.

28. A liquid fuel cell as claimed in Claim 24, wherein said gas vent ports (31, 310) are disposed at diagonally upper and lower positions of said fuel tanks (27, 270) respectively.

29. A liquid fuel cell as claimed in Claim 24, wherein the volume of one of said fuel tanks (27, 270) is more than two to five times as large as that of the other.

30. A liquid fuel cell including a fuel electrode (23) and an oxidizer electrode (21) disposed opposite to each other with a liquid-fuel impermeable electrolyte layer (24) being interposed therebetween, a fuel chamber (25) disposed adjacent to said fuel electrode, an oxidizer chamber (30) disposed adjacent to said oxidizer electrode, and a fuel tank (27) supplying liquid fuel to said fuel chamber, wherein at least two passages are provided so that fuel can be supplied from said fuel tank to said fuel chamber through a second passage (28a, 29a) when the

attitude of the fuel cell tilts over an angle of more than 45° from the normal attitude and fuel cannot be supplied through a first passage (28b, 29b) normally connecting between said fuel tank and said fuel chamber, said first and second passages cooperating to continuously charge fuel in said fuel chamber to ensure quick starting in response to the supply of an oxidizing agent to said oxidizer chamber, and means is provided for venting gas produced at said fuel electrode to the atmosphere.

31. A liquid fuel cell including a plurality of series-connected unit cells each including a fuel electrode (23) and an oxidizer electrode (21) disposed opposite to each other with an electrolyte layer (24) being interposed therebetween, a fuel chamber (25) disposed adjacent to said fuel electrode, and an oxidizer chamber (30) disposed adjacent to said oxidizer electrode, and fuel tanks (27, 270) supplying liquid fuel to said fuel chambers, wherein at least two vertically-spaced passages (28b, 29b, 280b; 28a, 29a, 280a) permitting communication of said fuel tanks with all of said fuel chambers are provided so that one of them serves as a first passage for liquid fuel while the other serves as a second passage for gas produced at said fuel electrodes, the liquid fuel in an amount smaller than the tank volume is charged in each of said fuel tanks to leave a non-charged space to accumulate gas produced at said fuel electrodes and conducted through said second passage, and gas vent ports (31, 310) provided with gas-liquid separating means (5) are provided on the

tank wall portions corresponding to said non-charged spaced defined in said fuel tanks.

32. A liquid fuel cell as claimed in Claim 31, wherein said gas vent ports (31, 310) are disposed at two or more positions including diagonally upper and lower positions of said fuel tanks respectively.

33. A liquid fuel cell as claimed in Claim 31, wherein said passages (28b, 29b, 280b; 28a, 29a, 280a) permitting communication of said fuel tanks with all of said fuel chambers are disposed at two or more positions including diagonally upper and lower positions.

34. A liquid fuel cell including a plurality of series-connected unit cells each including a fuel electrode (23) and an oxidizer electrode (21) disposed opposite to each other with an electrolyte layer (24) being interposed therebetween, a fuel chamber (25) disposed adjacent to said fuel electrode, and an oxidizer chamber (30) disposed adjacent to said oxidizer electrode, and fuel tanks (27, 270) supplying liquid fuel to said fuel chambers, wherein at least two vertically-spaced passages (28b, 29b, 280b; 28a, 29a, 280a) permitting communication of said fuel tanks with all of said fuel chambers are provided so that one of them serves as a first passage for liquid fuel while the other serves as a second passage for gas produced at said fuel electrodes, the liquid fuel in an amount smaller than the tank volume is charged in each of said fuel tanks to leave a non-charged space, and gas vent ports (98, 99) provided with gas-liquid separating

means (5) are disposed midway of said passages.

35. A liquid fuel cell as claimed in Claim 34, wherein said passages (28b, 29b, 280b; 28a, 29a, 280a) permitting communication of said fuel tanks with all of said fuel chambers are disposed at two or more positions including diagonally upper and lower positions.

FIG. 1

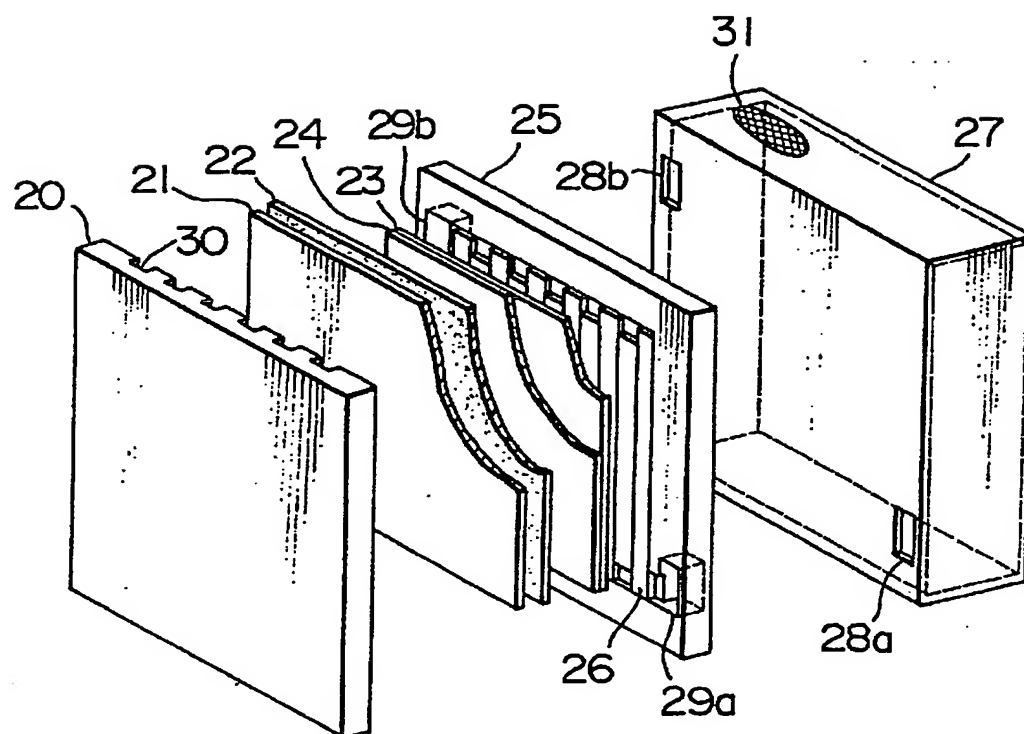


FIG. 2

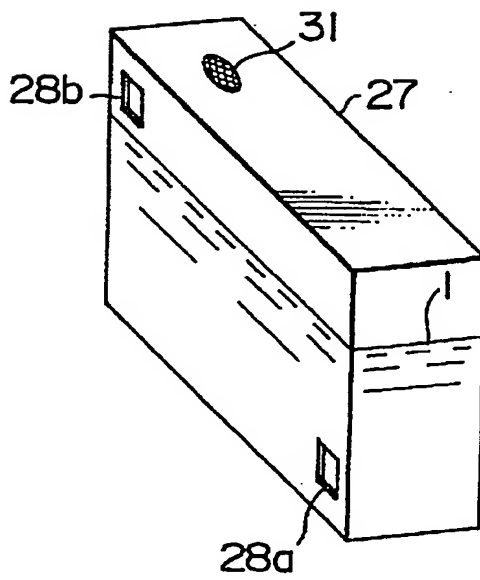


FIG. 3

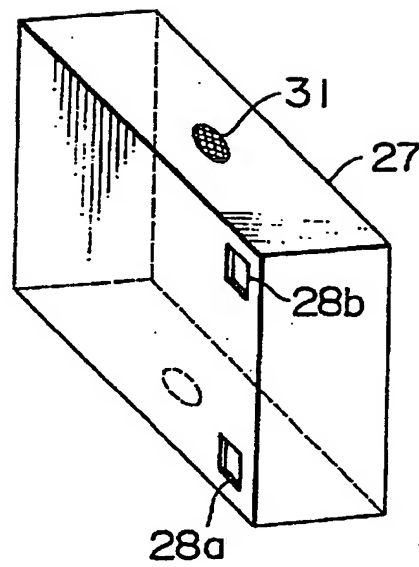


FIG. 4

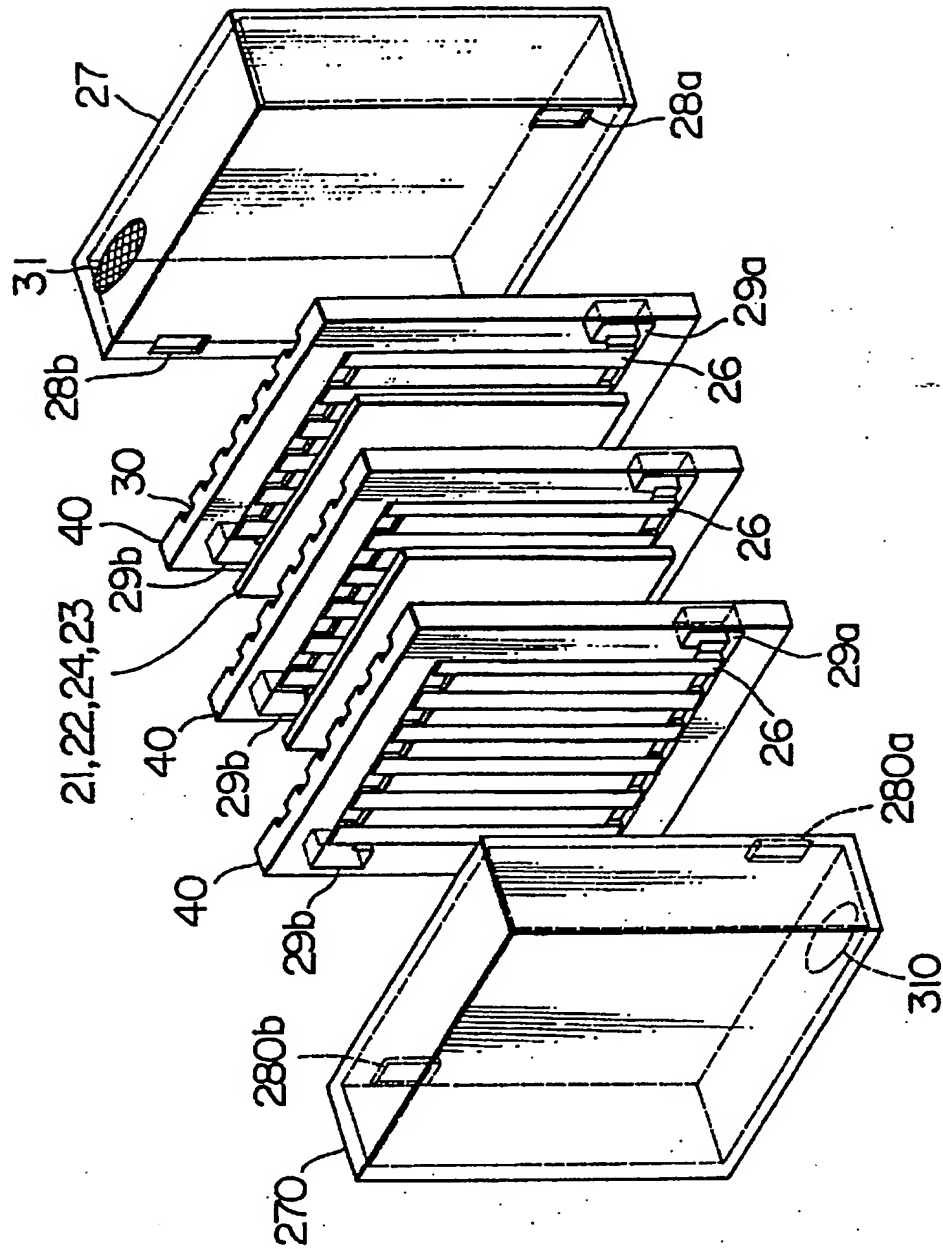


FIG. 5

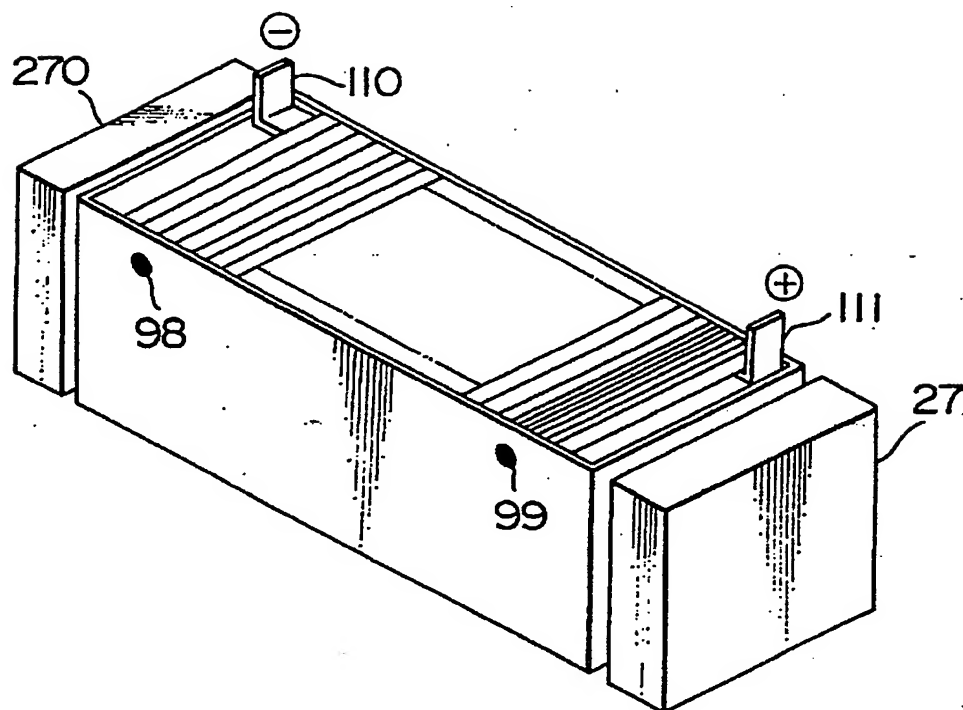


FIG. 6

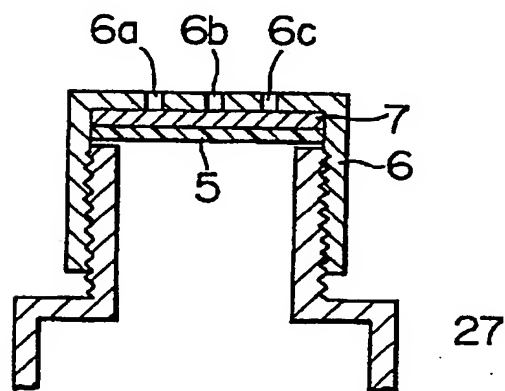


FIG. 7

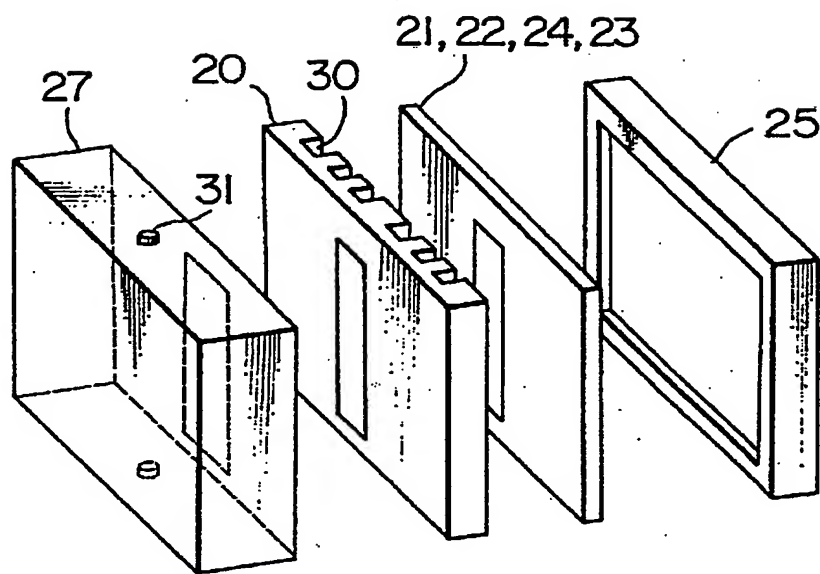
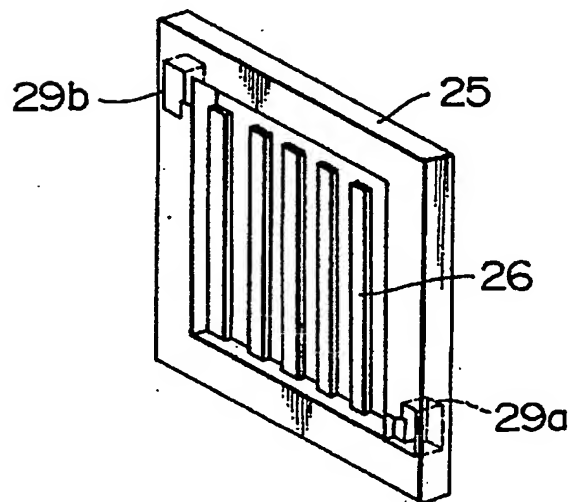


FIG. 8



**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☒ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☒ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☒ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.